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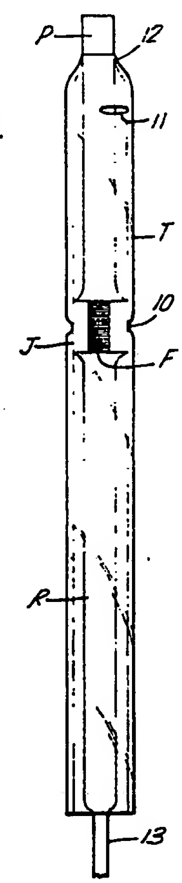
(54) Manufacture of optical fibre preforms

(57) The diameter of the outer waveguide of an optical fibre preform (P) is increased by sleeving it with a tube (T). Axial alignment of preform and tube is achieved by butt-welding the preform (P) endwise to a rod (R) and smoothing the cylindrical surface of the butt weld to match the inner diameter of the tube (T).

Irregularities in the diameters of core/cladding and outer waveguide of the preform (P) may be compensated for by stretching the combined preform (P) and tube (T) assembly before the addition of a further tube of known diameter.

Fig.2.



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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

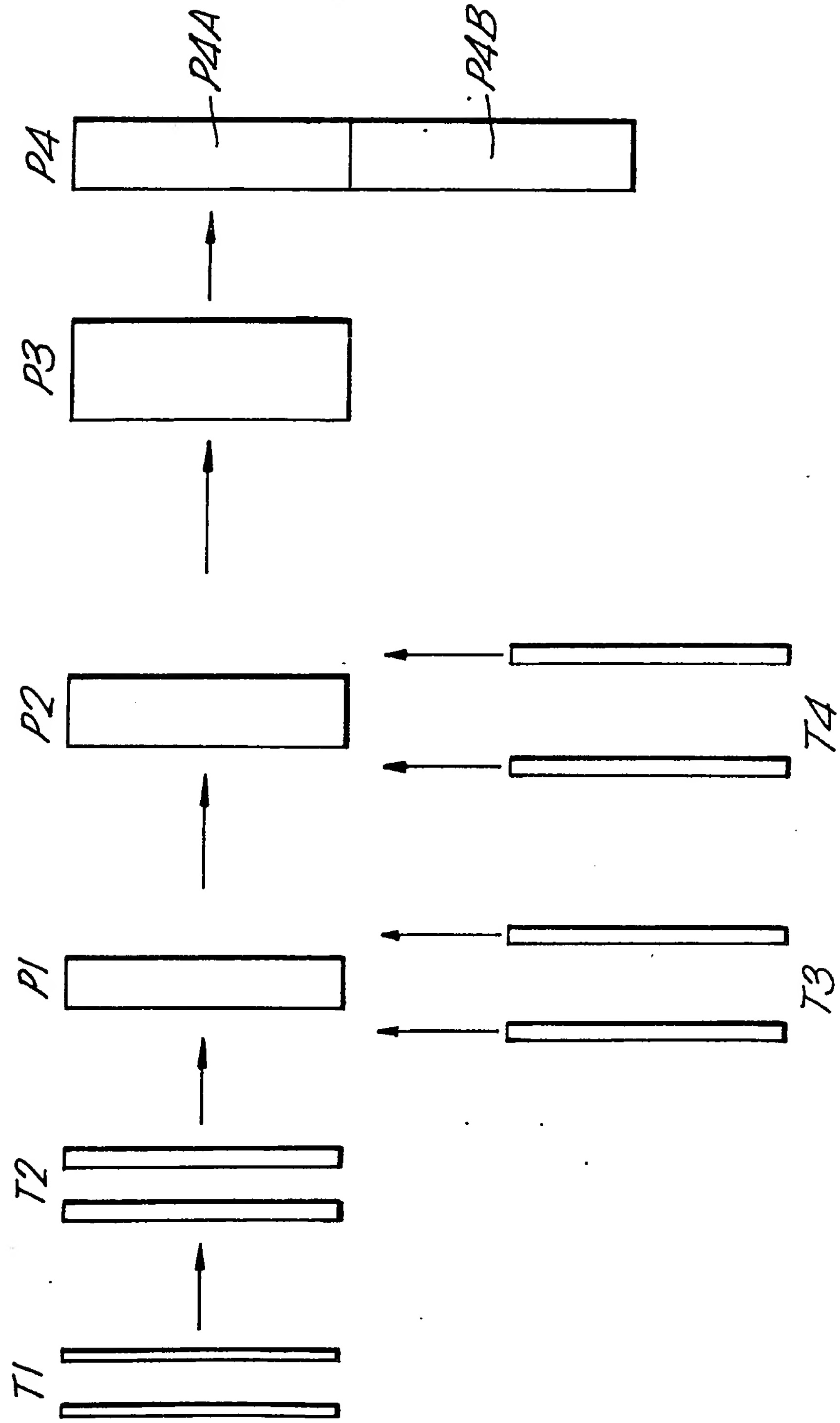


Fig.1.

Fig.2.

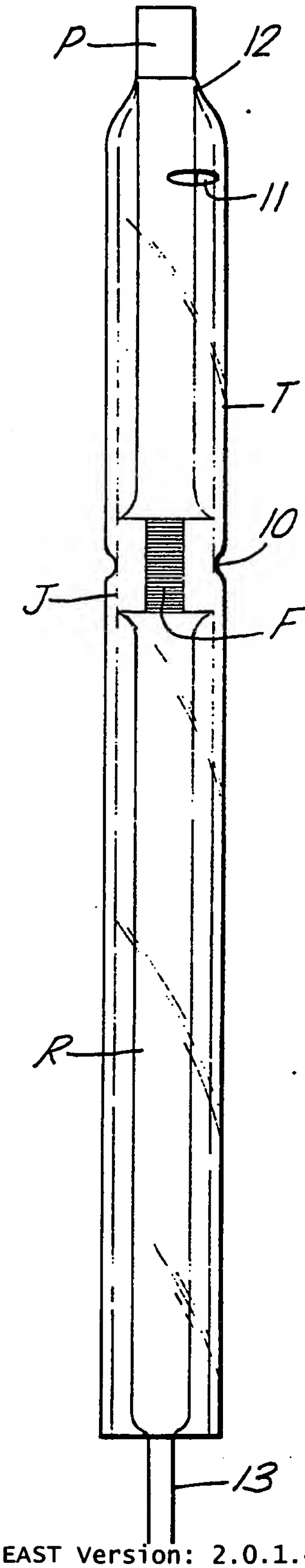
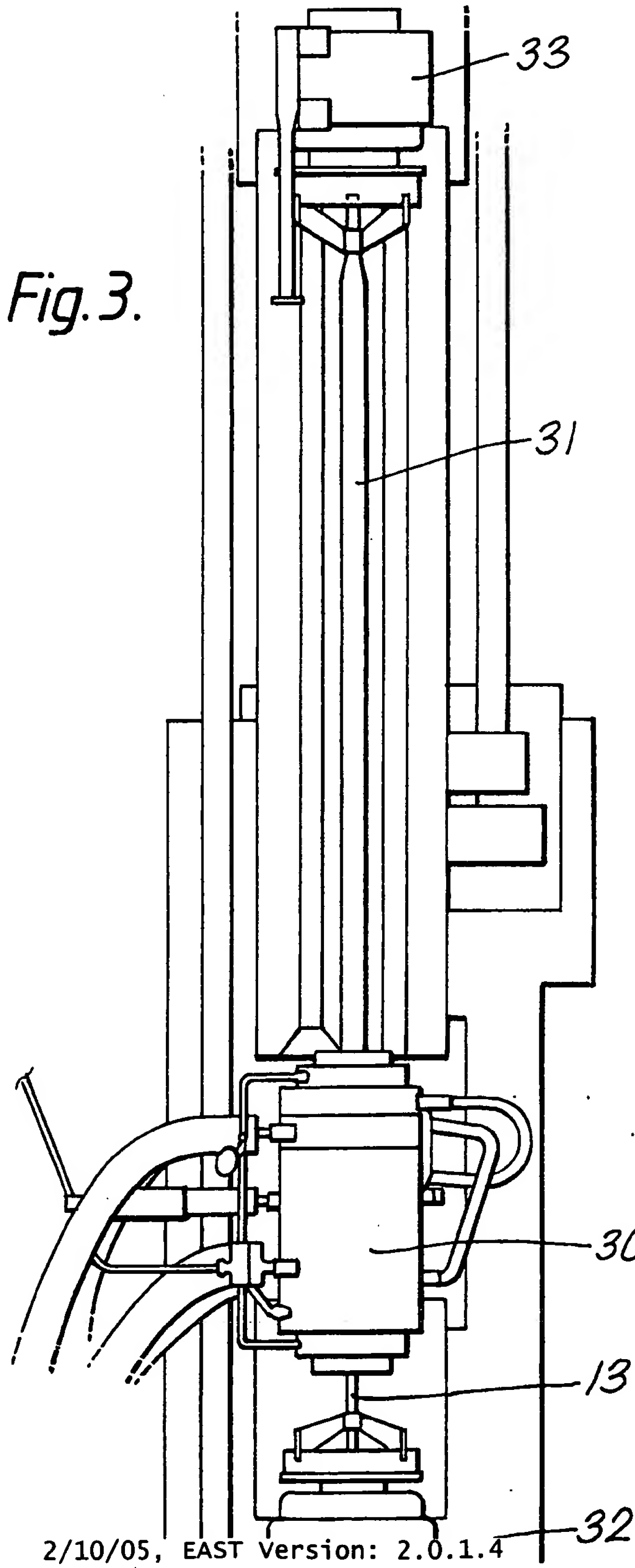


Fig. 3.



GPT/3796

Manufacture of Optical Fibre Preforms

This invention relates to the manufacture of optical fibre preforms, that is to the cylindrical glass preforms from which optical fibre is drawn, and in particular to a method of increasing the external diameter of a preform by the application of an extra tube of the same material.

Single mode optical fibre preforms consisting of a core and a cladding layer inside a thicker outer waveguide are typically manufactured by depositing the cladding and core layers successively by MCVD (modified chemical vapour deposition) onto the inner cylindrical surface of a substrate tube which is to form the outer waveguide. The substrate tube is then collapsed by heat treatment in a furnace to form a solid preform which is then drawn directly into optical fibre using the furnace. It is necessary to maximise the overall yield of optical fibre in relation to the time spent producing the preform: the yield is often expressed in terms of fibre kilometres per lathe hour. The obvious solution is of course to produce a larger preform with correspondingly thicker deposition layers, but the large wall thickness restricts the amount of heat from the furnace reaching the inner surface of the waveguide substrate, which makes the vapour deposition and the tube collapsing processes more difficult and time consuming.

Improvements in the yield have been achieved by increasing the thickness of deposition inside the same size waveguide tube, and

then collapsing onto the exterior surface a silica sleeve of the same waveguide material. In this way, the thickness of the waveguide is increased after the initial waveguide tube has collapsed into a solid rod. Silica tubes for this purpose are now commercially available in standard sizes.

Conventional methods of sleeving a solid preform in this way are relatively complex and time consuming because of the need for accurate axial alignment of the tube with the underlying preform rod: the clearance between these two elements may be of the order of only 1 mm. Inaccurate alignment results in variations in the thickness of the waveguide formed when the tube has collapsed onto the preform. This in turn reduces the concentricity of the outer surfaces of the core and of the overall waveguide. If this is so severe that a concentricity tolerance of 0.8 microns is exceeded in optical fibre of 9 microns diameter drawn from the preform, these figures being typical, then the preform is rejected.

According to a first aspect of the invention, therefore, a method of increasing the diameter of a solid optical fibre preform comprises butt-welding the preform endwise to a colinear glass rod of substantially the same diameter such as to form a cylindrical welded region, smoothing the surface of the welded region down to an external diameter of substantially the predetermined internal diameter of a cylindrical glass tube of the preform waveguide material which diameter is substantially greater than that of the remainder of the preform and the rod, sliding the glass tube coaxially as a sleeve over the preform and rod assembly, securing the tube to the welded region and to the other end of the preform, and applying heat to collapse the tube onto the preform.

The welded region ensures that the sleeving tube is spaced from the preform by a closely-controlled amount at a point intermediate the ends of the preform-and-rod asssembly, and moreover the cylindrical surface of the welded region ensures accurate alignment of the tube with the preform axis.

The step of collapsing the tube onto the preform may be performed simultaneously with the drawing down of the preform-and-tube assembly into optical fibre.

The sleeving and collapsing processes are best carried out with the preform held vertical, to assist in attaining and maintaining correct alignment of the tube and the preform axis.

A further problem associated with the conventional sleeving process is that some preforms have to be rejected because their core diameter is such that, once sleeved, the resultant preform would have an incorrect diameter ratio between the core and the overall waveguide. The MCVD process may not be capable of sufficiently close control to avoid the rejection of a proportion of the preforms; the use of commercially-available silica sleeving tubes available only in a limited range of sizes means that no compensation can be made at the sleeving stage to correct for a preform whose core or waveguide diameters fall outside strict tolerance bands.

According to a second aspect, therefore, the invention provides a method of increasing the diameter of a first solid optical fibre preform to produce a final preform, comprising determining the diameters of the core and the outer waveguide of the first preform, sleeving the first preform with a first glass tube of the waveguide material of a predetermined diameter and thickness while allowing a clearance between the preform and the tube, heating the sleeved preform to collapse the tube onto the preform to form a second preform and simultaneously stretching axially the sleeved preform to reduce the diameter of the second preform, then sleeving the second preform with a second glass tube of the same material of a predetermined diameter and thickness and heating it to collapse it onto the second preform in a similar manner to form the final preform, the degree of stretch applied to the first preform being calculated, as a function of the diameters of the preform core and outer waveguide and of the first and second tubes, such that the final preform has a predetermined core-to-waveguide diameter ratio.

The stretching process thus allows a subsequent compensation to be made for variations in the diameter of the core or of the waveguide in the initial preform, enabling most preforms to be used and not rejected.

The yield is improved by compounding the sleeving processes, building up the thickness of the waveguide through the successive addition of tubes of appropriate diameters. At each stage, the relevant properties of the solid preform may be monitored, in order to compensate as far as possible for any deviations by an appropriate degree of stretch of the preform at the next stage.

Optical fibre produced from preforms produced by the addition of at least one tube to an initial preform, has a refractive

index which changes from the core to the outer waveguide in virtually the same manner as would be the case if the core had been deposited on a larger substrate tube to which no further tubes were added. Microscopic variations in refractive index occur at radii corresponding to the boundaries between each successive preform and its sleeving tube, but these do not significantly affect the performance of the optical fibre.

For the avoidance of doubt, the invention also provides an optical fibre preform manufactured in accordance with the method in either of its aspects, and also consists in optical fibre drawn from such preform.

One way in which the invention may be performed will now be described, by way of example only, with reference to the accompanying drawings, in which :-

Figure 1 is a diagram, not drawn to scale, of the way in which an optical fibre preform is produced by the successive addition of silica tubes;

Figure 2 is a diagram, not drawn to scale, of an assembly of an optical fibre preform, a silica rod, and a sleeving tube, formed at an intermediate stage in a manufacturing method embodying the invention; and

Figure 3 is a schematic representation, in side elevation, of a vertical lathe with a furnace, for carrying out part of the method described with reference to Figures 1 and 2.

With reference to Figure 1, core and cladding layers are deposited by conventional MCVD techniques onto the inner surface of a silica substrate tube T1 which is one metre in length and has inner and outer diameters of 16 mm and 20 mm. The resulting tube T2 with rather thicker walls is then collapsed in a conventional manner to form a solid preform P1 of outer diameter 13 mm. Preform P1 would be capable of producing 6 km of optical fibre pulled at 125 microns outer diameter.

The preform P1 is then tested for concentricity of its core or cladding layers and its outer waveguide layer, and the diameters of one or both of the core and cladding layers and of the outer waveguide are determined. If the concentricity is within tolerance limits then the preform P1 is passed to the next stage.

A silica tube T3 identical to the original tube T1 is then placed over the preform P1, in a manner to be described in greater

detail below, and is collapsed onto the outer surface of the preform, thus forming a larger preform P2 of outer diameter approximately 18 mm. Preform P2 would be capable of providing 12 km of 125 micron outer diameter optical fibre.

The same process is then repeated, with the addition of a larger tube T4, still 1 m in length but with inner and outer diameters of 19 mm and 25 mm. This produces a still larger preform P3 with an outer diameter of 24 mm, capable of producing 20 km of optical fibre.

The process is optionally continued, using the same apparatus, by first elongating preform P3 to form preform P4 of twice the length, and dividing preform P4 into two identical preforms P4A and P4B. Each of these further preforms may then be built up in a similar manner, by the addition of one or more silica tubes of standard dimensions.

The amount of material in the core and cladding layers in the final preform is of course predetermined at the MCVD stage, and is selected in accordance with the required number of sleeving stages such as to produce a final preform with the correct diameter ratio between core (or cladding) and outer waveguide.

With reference now to Figure 2, the preform P, which may be any of preforms P1, P2, P3, P4A and P4B of Figure 1, has its diameter increased by the addition of a sleeving tube T. The preform P is butt-welded at a region J to a silica rod R of identical diameter; the preform and rod are placed into accurate axial alignment in a lathe and are then joined endwise as shown by the application of heat. As the preform P and rod R are pushed together, the welded region J expands in diameter as shown.

After it has cooled, the welded region J is machined to reduce its diameter sufficient to allow the tube T just to slide over it. The welded region J is given a smooth, cylindrical surface extending axially for a length at least equal to its diameter; the greater its length, the better it functions to align the axes of the tube T and the preform P.

The cylindrical welded region J is then machined to give it a flat F, in order to ensure an axial passage for the flow of gas once the sleeving tube T is in place. The transverse clearance between the rod R and preform P and the sleeving tube T is approximately 1.5 mm.

The sleeving tube T, of a type which is commercially available, is assembled onto the lathe, and is provided with a vent slot 11 at one end. The tube T is then slid over the preform and rod assembly, there being a close fit between the tube T and the welded region J. At this point, the vent slot 11 is in register with the upper end of the preform P.

The upper end 12 of the tube T is centred accurately around the preform P, and is heated to collapse it locally onto the upper end of the preform P. A hot tool is also applied to the tube T overlying a central portion of the welded region J, at angularly-spaced locations but not over the flat F, to melt the tube T onto the welded region J at three or more locations 10.

In order to ensure that the sleeving tube T is in correct axial alignment, and to facilitate the clamping of the assembly in the lathe, PTFE cones are preferably threaded over the preform P from one end and over the rod R from the other end and are plugged into the ends of the tube T (not shown).

Before the tube T is slid over the preform and rod assembly, the latter is cleaned by liquid phase etching in a mixture of acids, followed by washing in millipore water and drying. Once the sleeving is complete, as shown in Figure 2, the cleaning process is repeated. Alternatively, the entire assembly of Figure 2 may be cleaned by gas phase etching, applying oxygen and freon through slot 11 while heating the outside of the tube T, thereby etching both inner cylindrical surfaces.

The assembly of Figure 2 is then transferred to a vertical lathe, as shown in Figure 3, of which an upper clamp 33 secures the preform P and a lower clamp 32 secures a narrow diameter silica rod 13 attached to the principal rod R of the assembly. At this stage, of course, the PTFE cones have been removed.

An inert gas such as argon is made to flow upwards through the passage defined by the flat F and tube T and out through the vent slot 11. A furnace 30 is moved vertically upwards from a zone close to the welded region J up to the top region 12 of the tube T. This causes the tube T to collapse under surface tension onto the preform P, to form a homogeneous structure.

Simultaneously, the lathe is operated to introduce a slight axial stretch to the preform and tube asembly. The purpose of this

stretch is to allow for slight variations in the diameter of the core or cladding and/or of the diameter of the preform P, in anticipation of the next sleeving stage. The degree of stretch is such, in relation to the diameters which have already been determined, and to the predetermined inner and outer diameters of the sleeving tube T, that when a further sleeving tube is added in a subsequent stage, that tube also having standard dimensions, the diameter ratios in the final preform will be correct. For example, if preform P had been found to have a core with a relatively small diameter, the degree of stretch given to the preform and tube assembly would be relatively little so that when a further tube is added the diameter ratio between core and outer waveguide becomes normal.

Once the tube T has collapsed onto the preform P and has been cooled the resultant solid preform is cut at a point above the welded region J, and although it could be used immediately to produce optical fibre, it is usually further built up by the addition of one or more tubes T. At each stage, the solid preform is monitored, to measure the relevant diameters.

For greatest efficiency, the optical fibre is preferably drawn from the final preform simultaneously with the process of collapsing the final tube T onto the penultimate preform P.

CLAIMS

1. A method of increasing the diameter of a solid optical fibre preform, comprising butt-welding the preform endwise to a colinear glass rod of substantially the same diameter such as to form a cylindrical welded region, smoothing the surface of the welded region down to an external diameter of substantially the predetermined internal diameter of a cylindrical glass tube of the preform waveguide material which diameter is substantially greater than that of the remainder of the preform and rod, sliding the glass tube coaxially as a sleeve over the preform and rod assembly, securing the tube to the welded region and to the other end of the preform, and applying heat to collapse the tube onto the preform.

2. A method according to Claim 1, in which the step of collapsing the tube onto the preform is performed simultaneously with the drawing down of the preform-and-tube assembly into optical fibre.

3. A method according to Claim 1 or Claim 2, in which at least collapsing process is carried out with the preform held vertical.

4. A method according to Claim 3, in which the tube is collapsed onto the preform by heating over a zone which travels axially upwards from bottom to top in a single operation, while inert gas is arranged to flow axially within the tube throughout the length of the preform, rod and tube assembly.

5. A method according to any preceding claim, including forming an indentation along the full length of the welded region to provide a passage for gas between the space around the preform and the space around the tube.

6. A method according to any preceding claim, including forming an aperture in the tube at a position which, when it is in position over the preform, registers with the end of the preform remote from the welded region, to provide a passage for the flow of gas from the space between the tube and the preform.

7. A method of increasing the diameter of a first solid optical fibre preform to produce a final preform, comprising

determining the diameters of the core and the outer waveguide of the first preform, sleeving the first preform with a first glass tube of the waveguide material of a predetermined diameter and thickness while allowing a clearance between the preform and the tube, heating the sleeved preform to collapse the tube onto the preform to form a second preform and simultaneously stretching axially the sleeved preform to reduce the diameter of the second preform, then sleeving the second preform with a second glass tube of the same material of a predetermined diameter and thickness and heating it to collapse it onto the second preform in a similar manner to form the final preform, the degree of stretch applied to the first preform being calculated, as a function of the diameters of the preform core and outer waveguide and of the first and second tubes, such that the final preform has a predetermined core-to-waveguide diameter ratio.

8. A method according to Claim 7, in which the step of collapsing the second tube onto the second preform is performed simultaneously with the drawing down of the final preform into optical fibre.

9. A method according to Claim 7 or 8, in which the collapsing processes are carried out with the preform held vertical.

10. A method of increasing the diameter of a solid optical fibre preform, substantially as described herein with reference to the accompanying drawings.

11. An optical fibre preform when produced in accordance with the method substantially as described herein with reference to the accompanying drawings.

12. Optical fibre drawn from a preform according to Claim 11.